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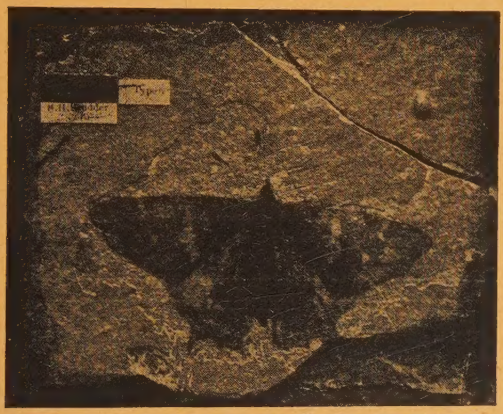

Prodryas persephone Scudder.

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VOL. XXV DECEMBER, 1918 No. 6

ON THE STRUCTURE AND FUNCTION OF THE PROVENTRICULUS OF *GRYLLUS PENNSYLVANICUS* BURM.

By E. Melville DuPorte,
Macdonald College (McGill University), Canada.

There are two explanations generally given of the function of the proventriculus in insects. The earlier writers regarded this organ as the analogue of the gizzard of birds, an organ for the mastication and comminution of the food in its passage from the crop to the mesenteron, hence the terms "gizzard," "gesier," "Kaumagen."

Another view, and one which perhaps has now the greater number of adherents, is that the teeth of the proventriculus have no triturating function but act as a strainer or grating to exclude solid particles of food from the mesenteron. While some writers deny completely the comminuting function of the proventriculus, others are willing to admit that in addition to its straining action it may sometimes have a triturating action. Still others hold that one of the chief functions of this organ is to thoroughly mix the food from the crop and prepare it for the action of the digestive juices in the mesenteron.

The writer hopes to show from a study of the structure of the proventriculus of *G. pennsylvanicus* and of the condition of the food in the crop, the proventriculus and the mesenteron, that in the Gryllidæ the proventriculus has a definite triturating function. The descriptions are limited to *G. pennsylvanicus* because for his purpose the armature of the proventriculus in all of the Gryllidæ studied by him is essentially similar.

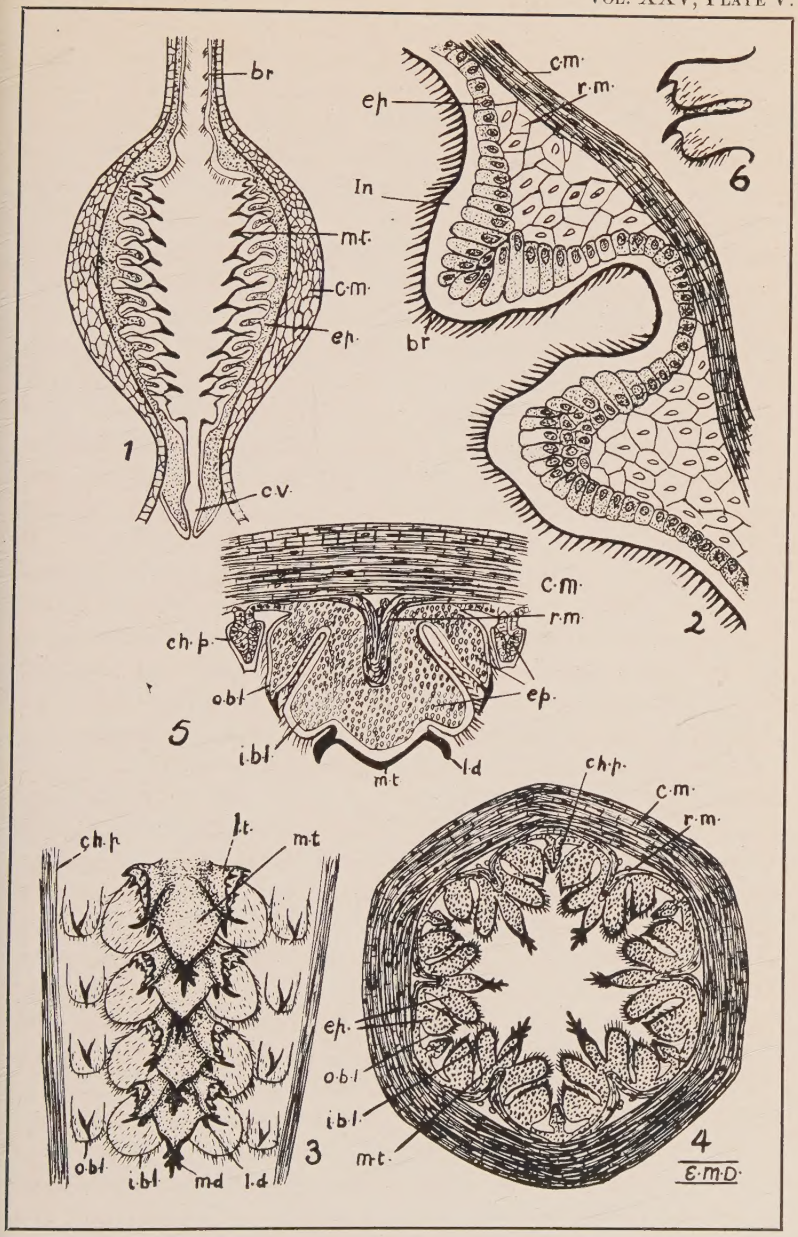
As the proventriculus of other species of the Gryllidæ has already been described the structure will not be given in very great detail.

The anterior division forms a tubular neck leading from the crop. The intima is thrown up into six folds each bearing ten

transverse rows of backward-directed bristles (Pl. V, br.), a few of these bristles, especially in the posterior rows, occasionally develop into small chitinous teeth. The tunic of circular muscles (c. m.) is only two or three layers thick and in each fold there is a band of longitudinal muscles (Pl. V, Fig. 2. r. m.).

The posterior division of the proventriculus is broadly oval and contains a complicated system of strongly chitinized teeth. The tunic of circular muscles is well developed, consisting in some places of ten or twelve layers. Within are six dental folds continuous with the folds in the anterior portion. These folds are separated by means of chitinous partitions (Pl. V, ch. p.). In each dental fold there are normally ten transverse rows of teeth, each row consisting of seven distinct teeth all directed backward towards the mesenteron. In the middle of the fold is the median tooth (m. t.), the only unpaired tooth in the row and the one which projects farthest into the lumen. At its apex it bears four to six sharply pointed, strongly chitinized median denticles (Pl. V, m. d.) and at each of its basal angles a single sharp lateral denticle (l. d.). Immediately in front of the median tooth is a pair of lateral teeth (l. t.); viewed from the inner side (*i. e.*, from the direction of the median tooth) these teeth are narrowly wedge-shaped; from the outer side they present a narrow curved surface around the edge of which are arranged eight small chitinous processes which convert this tooth into a grinder comparable to a molar. Behind the median tooth is a pair of large blunt pad-like processes (i. b. l.) not very highly chitinized as compared with the median and lateral teeth, and covered for the most part with a short yellow pubescence but on the anterior side with rather longer and stiffer hairs. Next the chitinous partition on each side is another brush-like process (o. b. l.) bearing a very sharp backward curving tooth. The two last described processes are termed by Berlese *i lobi a spazzola* so the writer has called them respectively the inner and outer barbated lobes.

The cells of the single epithelial layer of the chitinous partitions are clearly marked off. The epithelial cells of the various processes are not so distinctly marked, the numerous nuclei of the epithelium being very closely packed. Within each row of teeth there is a muscular band (Pl. V, Figs. 4 and 5 r. m.) which pulls the teeth outwards, enlarging the lumen and opposing the action of the circular band.



DUPORTE—Proventriculus of Gryllus.

Examination of the structure of the proventriculus with its complicated system of teeth—the sharp denticles fitted for cutting and tearing, the lateral teeth fitted for crushing and grinding—and its efficient mechanism for powerful compression can hardly fail to convince one that this organ has a definite triturating function; but the evidence does not lie in the structure alone but also in a consideration of the condition of the food in the crop, the proventriculus and the mesenteron.

Plateau, one of the foremost and most authoritative exponents of the theory that the proventriculus is exclusively a strainer, has shown in support of his contention that if a cockroach feeds on food rich in cellulose, which is not digestible in the crop, fragments are found unaltered as to form and size in the mesenteron. If it consumes an abundance of farinaceous food, starch granules which escape digestion in the crop are found uncrushed in the mesenteron. To the writer this evidence does not seem conclusive because if the proventriculus were efficient as a strainer, all large particles should be excluded from the mesenteron no matter what their nature, and we should find much solid food in the crop and only liquid food or finely divided solid food in the mesenteron. On the other hand, if the proventriculus has a masticating action, tough substances such as cellulose would be imperfectly triturated, while bits of food as small as starch grains might easily escape further comminution. The condition of the food in the different sections of the canal would depend on the nature of the food ingested. If the food is soft and easily crushed the contents of the crop and mesenteron will be similar to those described where the straining action is postulated. If the food contains hard or tough particles, not easily crushed, these will be forced through the proventriculus and solid particles of food will be found, not only in the crop, but also in the mesenteron.

An examination of the digestive canal of crickets which had been fed on miscellaneous food, including dead crickets and locusts, revealed the fact that the particles of chitin, quartz and woody tissue found in the proventriculus and mesenteron were fully as large as any found in the crop (Pl. VI, 1, 2, 3).

The crop of crickets which had been fed on dead insects contained large particles of soft animal tissue (Pl. VI, 4). The mesenteron contained only small pieces (Pl. VII). A similar re-

sult was obtained with crickets which had been starved for several days and then fed on grains of wheat. The crop contained large bits both of the hull and of the starchy endosperm. The mesenteron contained several large bits of hull but no pieces of endosperm as large as those in the crop (Pl. VII, 2, 3, 4).

It will be seen from the foregoing that as a grating for the exclusion of large particles from the mesenteron the proventriculus has, in the cricket, little or no efficiency, since it allows even fragments of quartz to pass through it. Indeed a study of the arrangement of the backward directed teeth and the strong muscular coat will make it evident that particles caught in the proventriculus will be forced towards the mesenteron. The action of the proventriculus might be compared with that of the rollers in a mill; anything caught between the rollers is carried onward, if it is strong enough to resist the breaking power of the rollers it will come out unaltered on the other side, if not it will be crushed.

In many insects the teeth of the proventriculus are so poorly developed that they can have little or no triturating action. In others this organ serves some special purpose as in the honey sac of the bee (Cheshire), or the combined pump and valve of the house fly (Hewitt). In the cricket, however, the structure of the proventriculus and the condition of the food after passing through it leave no room for doubt that this organ has a definite triturating function.

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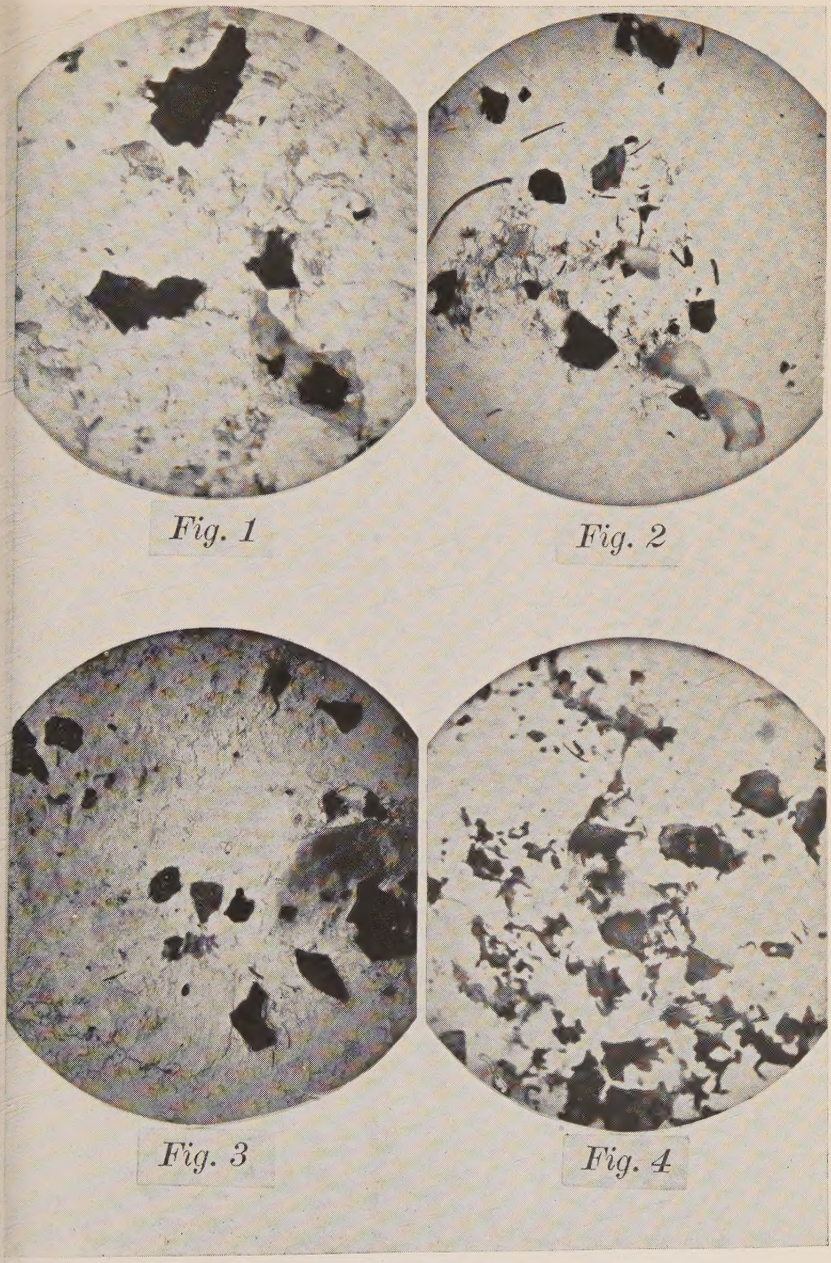

Fig. 1

Fig. 2

Fig. 3

Fig. 4

DuPorte—Proventriculus of Gryllus.

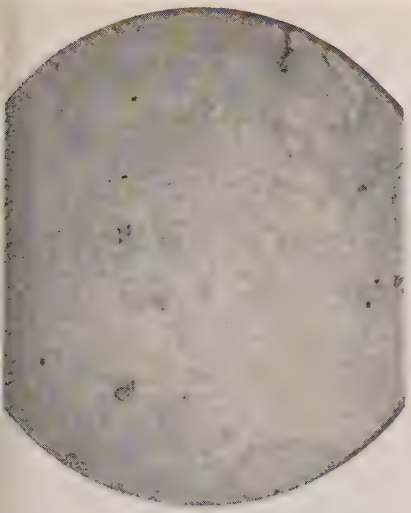

Fig. 1

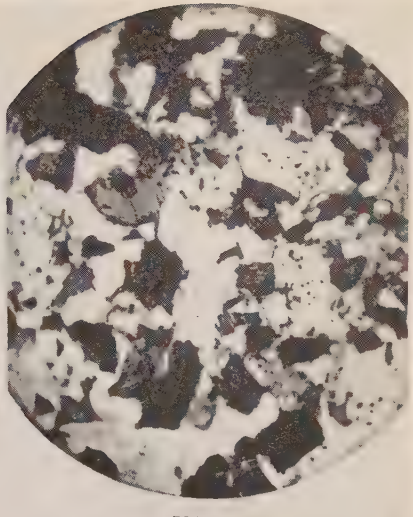

Fig. 2

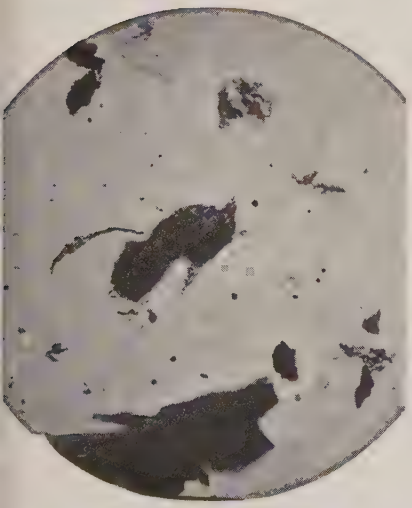

Fig. 3

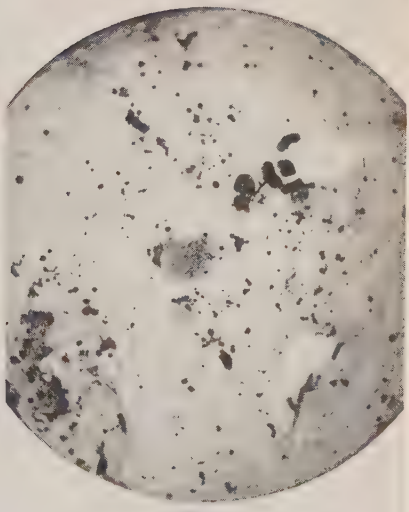

Fig. 4

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Explanation of Plates.

Plate V. Sections through the proventriculus of *Gryllus pennsylvanicus*. All greatly enlarged.

Fig. 1. Longitudinal section through the median denticles.

Fig. 2. Transverse section passing through two folds of the anterior division of the proventriculus.

Fig. 3. Surface view of a portion of one of the dental folds showing the chitinous partition and four of the transverse rows of teeth.

Fig. 4. Transverse section of proventriculus passing through the median denticles.

Fig. 5. Transverse section of fold cut in the region of the lateral denticles.

Fig. 6. Lateral view of two adjacent inner barbated lobes.

br. = Bristles of anterior division of proventriculus.
ch. p. = Chitinous partition between dental folds.
c. m. = Circular compressing muscles.
c. v. = Cardiac valve.
ep. = Epithelium.
i. b. l. = Inner barbated lobes.
in. = Intima.
l. d. = Lateral denticle.
l. t. = Lateral tooth.
m. d. = Median denticles.

m. t. = Median tooth.
o. b. l. = Outer barbated lobes.
r. m. = Relaxing muscle.

Plate VI. Photomicrographs of the contents of the digestive canal of cricket. Figs. 1, 2, 3 crop, proventriculus and mesenteron of cricket fed on miscellaneous food. Fig. 4, crop of cricket fed on dead insects.

Plate VII. Fig. 1 mesenteron of cricket fed on dead insects. Figs. 2, 3, 4 crop, proventriculus and mesenteron of cricket fed on wheat grains.

NEW POLYDESMOID DIPLOPODS FROM TENNESSEE AND MISSISSIPPI.

By Ralph V. Chamberlin,
Museum of Comparative Zoölogy.

Of the following underscribed species of millipedes one was collected in Mississippi at Agricultural College by Mr. J. W. Bailey, while the other four, three of them pertaining to a new genus, were taken by Professor R. Thaxter at Burbank in eastern Tennessee. The new genus is segregated from *Fontaria* sens. lat.

Fontaria pela sp. nov.

This species when in full color is above deep shining black with the caudal corners of the carinæ and the tip of the last tergite in life apparently bright red, fading in alcohol to brown or orange. There may or may not be a narrow stripe of the same bright color across the anterior border of the first tergite. The lateral region of each somite is in the main reddish or orange brown with a black stripe down the caudal portion from carina to legs, and a less distinct dark stripe in some along the anterior border as well. The antennæ are somewhat chestnut and the legs are brown.

The body is proportionately rather slender. It is parallel-sided excepting at the ends which are narrowed. The lateral carinæ are moderate in size; the caudal margins of the anterior ones are bent forward, those of the middle region less so, and those of the posterior ones first straight and then bent caudad, the posterior angles of the

last three acutely produced in increasing degree. Carinæ all depressed.

Head smooth and shining. Vertigial sulcus distinct, ending between antennæ often in a weak pit-like depression, a more obscure sulcus running from here to each antenna, the two forming a very obtuse angle. No occipital foveolæ detected in types.

In the male the genital processes of the second coxæ are short and cylindrical. The sternites are without processes excepting for low paired rounded bulgings on the third, fourth, and fifth somites. Coxæ unarmed.

The gonopods of the male are strongly pilose with long hairs on the mesal side at base, while the coiled blade is more sparsely provided with very short hairs. The blade of each gonopod curves ventrad and then across the other one, again bending dorsad and then back toward its own side as far as the middle line where it curves again ventrad at its tip; it narrows gradually distad, becoming slender, but near the end expands a little into a slightly lanceolate head which is acute and at the base of which on the concave side is a short tooth or spine; it is flattened throughout. The basal spine is rather stout and somewhat flattened with the acute apex bent at right angles to the main axis, and in some showing also a small acute point in line with the latter.

The males are ordinarily obviously smaller than the females.

Length of type (male) about 34 mm.; width, 7.25 mm. Length of a female near 40 mm., with the width 9 mm. The maximum male is 41 mm. long and 8.5 mm. wide.

Locality: East Tennessee; Burbank. Numerous specimens collected by Dr. R. Thaxter.

Fontaria ochra sp. nov.

The types are in general fulvous, with the legs and antennæ yellow, in most somewhat darker across the anterior region of the somites, though in the darkest individual of all the darkest part of the somite is in a narrow stripe slightly in front of the caudal margin. The general color appearance is much like that of *F. crassicutis* Wood. The carinæ in some are somewhat paler than the intervening region.

Body obviously narrowed at both ends, the sides over most of the length being parallel or nearly so. Lateral carinæ moderately

large, not raised at angle to general slope of somites excepting in caudal region. Posterior margin of carinæ in anterior region straight, slightly bent caudad in middle region, more so in posterior region, but only the last few acutely angularly produced.

Vertigial sulcus distinct, ending abruptly at or a little above upper level of antennal sockets. Occipital foveolæ 2+2.

In the male the sternites and the coxæ are without special processes.

In the gonopods of the male the principal or distal division is stout at the base and narrows gradually distad; it extends ventrad and then curves across to the other gonopod and then coils dorsad; near the point where it begins the bend dorsad it is somewhat geniculate, the portion beyond the geniculation being more slender and somewhat doubly or sigmoidally curved with the acute tip bend mesad almost at right angles; it is densely pilose at base on the mesal side and less strongly so along the edge to near the level where the bend across to the other side begins. The basal process is short, straight and acute and extends obliquely caudomesoventrad to near the tip of the principal process of the opposite gonopod.

Length of type (male) about 35 mm.; width, 10 mm.

Locality: Mississippi: Agricultural College. Six specimens collected in the fall of 1916 by J. W. Bailey.

Nannaria gen. nov.

Genotype—*N. minor* sp. nov.

In addition to the type species, *Fontaria tennesseensis* Bollman, *N. media* sp. nov. and *N. infesta* sp. nov., described below, belong in this genus. These forms are all small in comparison with *Fontaria* and are characterized in the main by the structure of their male gonopods in which the principal process is rather short and nearly straight or only moderately curved, never coiled, and not ordinarily passing the median line or crossing that of the other side, and in which the basal process is relatively long and slender. The genus will be critically defined and discussed in another place.

Nannaria minor gen. et. sp. nov.

This is a small species comparable in size to *F. tennesseensis*. The general color of the dorsum in the types is a dull, in one speci-

men somewhat smoky brown with the lateral carinæ paler, yellowish. A dark median longitudinal dorsal line is evident in the posterior portion. Antennæ and legs yellowish.

A slender species narrowed decidedly at the ends but elsewhere uniform in width. The posterior margins of the anterior somites are bent back slightly, those of the succeeding ones in going caudad more and more strongly so. The posterior corners of the last three pairs of carinæ strongly produced caudad but not acute, the distal ends being strongly rounded, the corners of the others more angular.

Vertigial sulcus ending as usual at the angle of a transverse arcuate sulcus between the antennal sockets, the latter sulcus much weaker than the vertigial and becoming obscure toward the ends.

In the male the sternites in the region caudad of the gonopods are produced at the ends, adjacent to the legs, caudad into sharp, straight conical processes; on the anterior half of the fourth somite are two distally rounded, subconical processes. The genital processes of the second coxæ are slenderly conical and short and project subcaudad. Coxæ unarmed. In what is regarded as the female of this species the sternites are not produced but the coxæ of the middle and posterior regions are at their distal ends produced ventrad into acutely tipped conical processes which decrease in size in going cephalad.

The species is readily distinguished by the character of the male gonopods. The principal branch is above the basal joint subcylindrical to below middle of length where it is abruptly narrowed into a slender blade which is moderately curved, but not at all coiled, its acute tip meeting that of the opposite gonopod at the median line. The caudal branch is long though not quite reaching the end of the main branch; it presents a decided double or sigmoid flexure, the acute tip bending across that of the other one; at the level of the first flexure on the ventral side there is a short acute spur.

Length of type (male) near 27 mm.; width, 5.5 mm.

Locality: East Tennessee: Burbank. A male and female collected by Dr. R. Thaxter.

Nannaria media sp. nov.

When in full color this species is deep chestnut above with the posterior corners of the lateral carinæ yellow. Beneath the color

is yellowish brown. On each somite between carina and legs of each side two dark stripes, one anterior and one posterior in position. The legs are brown, the anterior ones more reddish or chestnut, the antennæ typically still deeper in color.

The body is slender as in *minor*. The posterior margins of the lateral carinæ in the anterior region are straight, in going caudad becoming more bent back as usual though none of the posterior corners are really produced excepting those of the last three pairs of carinæ. The processes of the last three pairs of carinæ are broad and blunt, but not so evenly rounded as in *minor*, the mesal edge between apex and base bulging more than in that species.

The vertigial sulcus is deep. It bifurcates into two weaker sulci below, these not forming a distinct arcuate sulcus, the ends not evidently approaching the sockets of the antennæ as transverse lines. Occipital foveolæ 2+2.

In the male none of the sternites bear processes in either the posterior or anterior regions. The processes of the second coxæ are very short and comparatively thick. Coxæ unarmed in both sexes.

The male gonopods in general similar to those of *minor* but the principal branch not abruptly narrowed below a cylindrical base, the process gradually narrowing from base to the apex and geniculate near beginning of distal third of length, the apex not meeting that of the other gonopod. The distal portion flattened in a subvertical plane, distally truncate with upper and lower corners minutely acutely produced; also a point below a little proximad of end. The posterior spine is very slender and finely acutely pointed, and is nearly straight above its base, running subparallel to the main process than which it is much shorter, but the extreme apex curving somewhat ectad.

Length of type (male) about 30 mm.; width, 5 mm.

Locality: East Tennessee: Burbank. Two males and a female collected by Professor R. Thaxter

Nannaria infesta sp. nov.

Carinæ and caudal borders of metazonites dilute red, probably bright red in life; metazonites elsewhere olive, the dark color intruding on the carinæ anteriorly; prozonites olive grey.

Body slender, more strongly narrowed cephalad and caudad than in media, the attenuation caudad being especially pronounced and gradual. The processes of the last carinæ shorter and much broader than in media; the processes of the two preceding segments differ in having the mesal margin much less oblique and more nearly symmetrical with the outer one, caudally rounded. The caudal extension of the posterior ends of the carinæ begins farther forward than in media.

Vertigial sulcus very deep, ending below on a level with the centers of the antennal sockets, not truly bifurcate through there is a vague fine line from its lower end to each antennal socket.

Sternites without processes.

Principal processes of gonopods gradually narrowing distad much as in media, but the glabrous distal region shorter and curving more abruptly and more decidedly mesad, the distal, subvertical edge not obtusely excised as in media. The minor dorsal (anterior) processes more slender than in media and not subparallel, extending each obliquely mesodistad.

Length of type (male) near 35 mm.; width, 5.5 mm.

Locality: North Carolina: Cranberry (Coll. Aug. 6, 1896. Rec'd for study through Prof. R. Thaxter.)

The type is abundantly infested with an Empusa. It is in the collection of the Department of Cryptogamic Botany at Harvard University.

A NOTE ON *LIMATUS DURHAMI* THEOBALD.

By C. S. Ludlow.

An interesting omission in the available descriptions of this species, so far as the English and American authorities at least are concerned, was brought to my attention by the receipt of specimens sent by Colonel W. H. Wilson, M. C., United States Army, from the Canal Zone.

Neither in Mr. Theobald's description[1] nor in that given by Howard, Dyar and Knab[2] is mention made of a very noticeable and

[1] Theobald, F. V., Monograph, Culic. II, p. 349. 1901. Ibid., III, p. 333. 1903.

[2] Howard, Dyar and Knab, Monograph, The Mosquitos of North and Central America and the West Indies, III, p. 40. 1912.

beautiful marking on the male proboscis, and because of this omission I was led to hope that a new species had been sent me. However, comparison with the males at the National Museum showed the same marking on the specimens there, and then I found in the description of *Simondella curvirostris* Lavéran[1] quoted in the monograph of H. D. & K. the following:

"Près de son origine elle est sombre à la face supérieure et présente, à la face inférieure un petit disque ovale garni d' écailles d'un bleu très vif."

As a matter of fact this little oval group of scales is very brilliant and suggests a sapphire set in the dark proboscis.

As this marking seems to have escaped entirely the notice of both the authorities mentioned it is perhaps worth while to call attention to it.

Army Medical Museum,
Washington, D. C.,
August 14, 1918.

NOTES ON *CLOSTEROCERUS CINCTIPENNIS* ASHM.,[2] IN NEW JERSEY (HYMENOPTERA)

By Harry B. Weiss and Alan S. Nicolay
New Brunswick, N. J.

This species not heretofore recorded from New Jersey has been found by us at the following localities: New Brunswick, Jamesburg, Highbridge, Trenton, Bridgeton and Plainfield, and undoubtedly occurs in many other places in the state. It was described by Ashmead in his paper "Descriptions of Some New North American Chalcididæ" which appeared in Vol. XX, p. 104–1888 of the "Canadian Entomologist" and the habitat given is United States. It is also listed in "The Hymenoptera or Wasp-like Insects of Connecticut" as probably occurring in that state. Neither of the above publications mentions the hosts.

In New Jersey we have found *C. cinctipennis* to be parasitic upon the eggs and larvæ of *Brachys ovata*, the eggs of *Brachys aerosa* and

[1] Laveran, C. R., heb. Soc. Biol., liv. 1160. 1902.
[2] Identified by A. B. Gahan.

the larvæ of *Phyllonoryter hamadryadella* and *P. ulmella*, all of which are leaf miners. Its habits are therefore similar to those of other members of the genus and allied genera. During the summer of 1918, it appeared to be more common in the *Brachys* eggs and the larvæ of *P. ulmella* than in the other hosts and only on one occasion was it bred from the larva of *Brachys ovata*. It constituted a serious pest in the eggs of *Brachys* sp., which we were trying to rear and was very common in the mines of *P. ulmella*. Adults of *C. cinctipennis* were most plentiful about the first week of July and the pupal stage required about two weeks.

The eggs of *Brachys ovata* and *B. aerosa* are too small to support more than one parasitic larva but the mines of *P. ulmella* sometimes contained as many as six pupæ and the size of the mine indicated that only one larva of *P. ulmella* had been present. All of the *Brachys* egg except the shell is consumed by the larva of *C. cinctipennis* and pupation takes place within the shell. In the case of the larva of *P. ulmella*, everything is consumed except the outer skin and the alimentary canal and pupation takes place anywhere within the mine. The eggs of *Brachys* which are normally whitish and semitransparent before hatching become black when parasitized. The larvæ and pupæ of *C. cinctipennis* appear to be very similar to those of other members of the family.

Larva: Length 1.35 mm. Width 0.4 mm. Grublike, whitish, subcylindrical, glabrous, rounded anteriorly, pointed posteriorly, anal segment divided, segmentation indistinct, oral cavity on median ventral surface of head, mandibles almost invisible.

Pupa: Length 1.4 mm. Width 0.5 mm. Naked, shining black. The pupa is anchored to the floor of the mine with its posterior end within the cast skin of the larva. Upon holding the leaf up to the light the pupa is seen to be surrounded by from five to eight dark spots arranged more or less symmetrically. These dots are the ends of excrement like supports or beams which run from the roof to the floor of the mine and which undoubtedly prevent the upper and lower leaf surfaces from caving in on the pupa and probably interfering with development. These supports are also present in the parasitized *Brachys* eggs.

Adult: The following is Ashmead's description of the male:

"Length .04 inch. Head, pleura, sternum, metathorax and abdomen blue; collar, mesothorax and scutellum golden green

strongly punctate. Head emarginate in front and consequently very thin anteroposteriorly. Antennæ brown-black, hairy. Legs brown, trochanters, tips of tibiæ and tarsi pale or whitish. Wings hyaline, fringed with long hairs, forewings with a brown band extending across the stigmal region and another at the apical margin."

FIRST ACCOUNT OF A THERMOTROPISM IN *ANOPHELES PUNCTIPENNIS*, WITH BIONOMIC OBSERVATIONS.

By Werner Marchand.
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In the fall of 1915, while taking part in a survey of the breeding-places of Anopheline mosquitoes in the neighborhood of Princeton, in coöperation with the local Mosquito Extermination Commission, the writer made certain observations on the mosquitoes encountered. This account is restricted to a few facts which appear to be new or serve to clear up some doubtful point in the life history of the mosquitoes.[1]

I. *Bionomics of the Larvæ.*

In the Princeton region, only two species of Anopheles have been recorded, these being *A. quadrimaculatus* and *A. punctipennis*. The latter species is by far the more common, but, since King's experiments (1916),[2] it cannot be regarded as entirely harmless. It is doubtful, however, whether this species, which has been found to occur as far north as Boston, Mass. (Th. Smith),[3] is also in the northern states a regular carrier of malaria.

The larvæ of *A. punctipennis* were kept captive in large numbers and lived best in a flat dish which was left uncovered in order to give free access to the air. In a dish about eight inches in diam-

[1] The writer wishes, on this occasion, to express his thanks for the kind helpfulness through which his work was facilitated by Professor E. G. Conklin and Professor Ulric Dahlgren of Princeton University. Dr. Conklin also had the kindness to revise the English of the MS.

[2] King, W. V. Experiments on the development of malaria parasites in three American species of Anopheles. Jour. Exp. Med., Vol. 23, pp. 703–716, 1916.

[3] Theobald Smith. Notes on the Occurrence of Anopheles punctipennis and Anopheles quadrimaculatus in the Boston suburbs. Jour. Bost. Society of Medical Sciences, Vol. V, pp. 321–324, 1901.

eter, filled to a depth of about one and one-half inches with water from a pond, more than two hundred Anopheles larvæ, mostly collected in a half-grown stage, many of them in very young stages, developed into pupæ. The pupæ when formed were taken out with a pipette and transferred to another jar with provisions for the adults to hatch.

In order to rear Anopheles larvæ successfully, it is necessary to feed them, and this fact has not been sufficiently emphasized. It was found that certain unicellular surface algæ, the species of which could not be determined, form a very satisfactory food. These algæ developed freely in one of the glass-covered aquaria in the Vivarium of Princeton University. In this aquarium they covered the whole surface of the water in a continuous green sheet, which was wrinkled and folded in places through the excessive development of the algæ. In order to transfer these to the culture dishes it was sufficient to dip the finger into this stratum and then dip it into the Anopheles-basin; here the algæ, upon reaching the clear surface of the water, would immediately spread out over the whole surface in the form of a thin, opaque, green layer. The Anopheles larvæ would at once start feeding upon these minute algæ, a clear area soon forming around the head and mouthparts of each larva. Before evening, the larvæ had cleared the whole surface of algæ. The procedure was repeated at night in order to provide food for the larvæ to last until the next morning, when again the algæ had been completely devoured. In this way they were fed regularly twice daily. Under ordinary conditions, when Spirogyra or other filamentous algæ are given as food (C. A. Smith),[1] many larvæ usually die, because, as a matter of fact, their natural way of feeding is at the surface. Howard, Dyar, and Knab (1912)[2] suggest that, to provide food the jars in which Anopheles larvæ are grown, should be kept uncovered, "in order that the dust from the air may settle continuously upon the water." Undoubtedly, the Anopheles larvæ may feed on surface bacteria or protozoa, but in absence of green plants, the contamination of the water often causes death. When surface algæ are given, as in the case here recorded, practically no larvæ are lost, because these algæ produce oxygen

[1] Cora A. Smith. The Development of *Anopheles punctipennis* Say. Psyche, Vol. XXI, p. 1.

[2] Howard, Dyar, and Knab. The Mosquitoes of North and Central America and the West Indies. Vol. I, 1912.

in abundance, and the water does not have to be renewed at all. The quantity of algæ devoured by the larvæ was quite considerable. Lack of attention to this detail may perhaps explain the frequent failures in rearing Anopheles larvæ.[1] On the other hand, the use of surface algæ as food may serve to determine with exactness the quantity of food consumed by a single larva, since the algæ, under carefully chosen conditions, cover the surface quite evenly in a layer of measurable thickness, and therefore the quantity of algæ present on a surface of given dimensions and consumed in a given time may be estimated or calculated, and, divided by the number of larvæ feeding on this surface, would give the quantity consumed by a single larva. However, as the season was advanced, and the larvæ were transforming into pupæ, this experiment was not carried out.

The larvæ showed in a remarkable degree the characteristic instinct spoken of by Zetek,[2] to drop to the bottom when a shadow passed over their heads. When the writer came near them, in the morning, after they had been completely undisturbed for many hours, the phenomenon was particularly striking. The larvæ would drop almost simultaneously and then would remain at the bottom for several minutes.

In this connection, it may be noted that Graham has stated that, in the Sudan, microscopic fresh-water algæ form the principal food of Anopheles, a fact not unimportant for their control, since it may be that the mosquitoes may be kept in check by methods aiming at a destruction of the algæ.[3]

II. *Bionomics of the Adult Stage.*

The resting position of Anopheles has often been used as a characteristic to distinguish the malarial mosquito from other species, the Anopheles holding the body, as a rule, at a certain angle to the surface on which they are resting. This angle is, in *A. punctipennis*, usually about 45°; Nuttall and Shipley's illustration as reproduced

[1] W. M. Graham (A study of Mosquito larvæ, Jour. Ent. Research, Vol. I, 1910) has stated correctly that failure to rear the larvæ is not to be wondered at when it is recognized that mosquito larvæ require a constant supply of special food, consisting usually of living fresh-water algæ. In the absence of algæ the larvæ become cannibalistic and destroy one another.

[2] Zetek, James. Behavior of *Anopheles albimanus* Wiedemann and tarsimaculatus Goeldi. Ann. Ent. Soc. of America, VIII, 1915, p. 221 ff.

[3] Graham, loc. cit.; these algæ were not surface algæ but were suspended in the water; as stated, however, the Anopheles larva is mainly a surface feeder.

by J. B. Smith (Mosquito-control exhibit, N. J. State Museum),[1] in which it is represented to form a right angle with the surface, is an extreme case and not quite typical. It seems, however, that mosquitoes which rest for many hours in the same place, assume a more oblique position than do these which have just alighted. These characteristics apply only to *Anopheles punctipennis*, not to *A. quadrimaculatus*. Hibernating females of the latter species were observed beyond doubt in a resting position in which the body was held about parallel to the resting surface, as illustrated in the accompanying drawing from nature (Fig. 1). Hence, they can be easily mistaken for Culex if only the resting position is taken as a criterion.[2]

Fig. 1. Resting position of hibernating female of *Anopheles quadrimaculatus*. Sketch-drawing from Life.

Concerning the biting position of Anopheles, Nuttall and Shipley's illustration (J. B. Smith, N. J. State Museum exhibit) is not entirely correct (Washburn),[3] and H. P. Johnson[4] is in error in assuming that the mosquito must necessarily bite with proboscis inserted at a right angle. As a matter of fact, *A. punctipennis* will insert the proboscis usually at an oblique angle, the mosquito biting in a position much like the resting position, and the line of the proboscis forming the continuation of the longitudinal axis of the body. This is evidently of advantage for the sucking mechanism.

III. *The Biting Instinct due to a Thermotropic Reaction.*

Observations were also made on the biting instinct, which as it seems, is determined mainly by thermotropism. Patton and Cragg (1913) have reported[5] that Howlett observed that females of

[1] Nuttall and Shipley. The structure and biology of *Anopheles maculipennis*, Jour. of Hygiene, 1901.

[2] Howard (loc. cit. p. 205) has recorded the same fact for *A. quadrimaculatus* hibernating in barns in southern Idaho.

[3] Washburn, F. L. Economic Entomology at the World's Fair. Science N. S., Vol. XX, No. 518, 1904, and "The Biting position of Anopheles." Science, N. S., Vol. XXI, p. 228, 1905.

[4] J. B. Smith. How does Anopheles bite? Science, N. S., Vol. XXI, pp. 71–72, 1905.

[5] Patton and Cragg. Textbook of Medical Entomology. London, Madras and Calcutta, 1913.

Stegomyia scutellaris were attracted by the hot air radiating from a test tube filled with hot water. On the other hand, shed blood and sweat did not attract the ♀ ♀ of this species and *Culex fatigans* any more than water. Howlett's experiments were not known to me at the time when these observations were made, and since they were obtained independently of other observers, and the phenomenon was not known to apply to Anopheles, I may briefly report on them here, especially as data on thermotropism in insects are very scanty. The Anopheles which were kept in lamp chimneys for other purposes, were fed on apple jelly which was spread out on a glass plate. In order to prevent the mosquitoes soiling their legs and wings, the jelly was covered with filter paper. In the intention of providing a food as natural as possible, I heated the apple jelly on the glass plate, assuming that it would then be taken more readily. This was in fact the case. The mosquitoes came quickly to the filter paper and would bite through it as if it were human

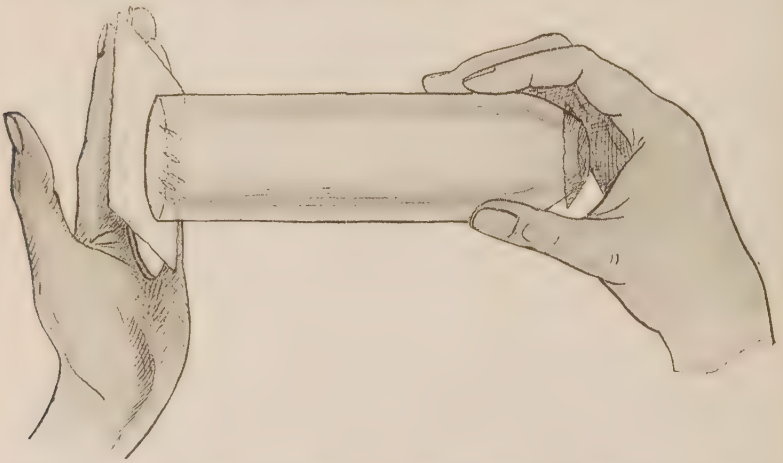

Fig. 2. Arrangement used in demonstrating the thermotropism of mosquitoes.

skin. The question suggested itself whether they were attracted by the odor of the jelly or, possibly, by the heat radiating from it. Being curious whether the mosquitoes would be attracted also by heat alone, I substituted for the glass plate which was covered with jelly, a clean one which was heated to a degree fairly above human body temperature but, of course, not excessive, and covered with

filter paper in the same way as before, in order to provide a foothold for the insects. The mosquitoes were attracted under these conditions in the same way as if food had been present, each one attacking the surface of the filter paper which covered the glass plate, and all bending their proboscis in repeated efforts to pierce the surface. The number of mosquitoes used was about five or six at a time. The arrangement was that given in the diagram (Fig. 2). If several mosquitoes are used in biting experiments, there will usually be some individuals which will show no inclination to bite, but the percentage of individuals not attracted by the heated glass plate, was about the same, and not greater than in the biting experiments. The males showed the same tropism as the females but much less strongly. As soon as the glass plate had cooled off, the mosquitoes became indifferent. However, the experiment could be repeated with the same mosquitoes as also with different sets and always with the same results.

These observations, taken together with those made by Howlett, indicate that this thermotropic reaction is a very important factor to be considered in the analysis of the bloodsucking instinct.

I have, since, tried to confirm these facts by observations on other species of mosquitoes, but so far have used only the hibernating females of *Aëdes sylvestris*. These, however, did not show even a trace of the thermotropic reaction observed in A. punctipennis. On the other hand they also consistently refused to bite, though various food other than blood was readily accepted. Females of Anopheles are known to bite occasionally in winter, and therefore, usually hibernate in stables where blood can be obtained (Grassi and others; see Howard, Dyar and Knab),[1] while Aëdes which hibernates in cellars, seems not to bite at all during the winter even if brought into a heated room. The absence of thermotropism would, therefore, in this case, be only an adaptation to the conditions of hibernation, during which no blood food is taken, and it is perfectly possible, that *Aëdes sylvestris* will be found thermotropic during the "biting season" unless, in this genus, other tropisms are involved.

[1] Loc. cit. p. 206–209.

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